



"I have found so much fun, with all these groups of internet people"

Peter Kirstein ARPANET international pioneer.

Early in the development of the Internet, he co-authored (with Vint Cerf) one of the most significant early technical papers on the internet concept. His research group at UCL played a significant role in the very earliest experimental Internet work. He became Professor of Computer Communications Systems at UCL in 1970, and brought the first ARPANET node to Europe in 1973.



Interviewed Oct 31st, 2006 at the Kelvedon Hatch secret nuclear bunker (UK)

I was born in Berlin, Germany in June 20th, 1933. However, I left Germany when I was three and a half years old. For obvious reasons, having left at that age, I wouldn't consider myself German, I would consider myself British. About my studies, I went to Cambridge, England from 1951 to 1954 but the British system was that you took your scholarship exams to University and then I had nine months or a year and nine months to spare. Many people went to the ARMY then

(we still had conscription), but I actually went to California and spent 9 months in UCLA. Then I came back to do a degree in mathematics and engineering at Cambridge. During this period I had a couple (1951 and 1952) of summer jobs with the ARMY engineers in Los Angeles. So I had a UK-US background already then. I went back to the US and got my PhD in Electrical Engineering from Stanford in 1957. Then I went back to Europe initially for 1 year. As I wanted to go skiing, I joined CERN in Geneva. I stayed there for 4 years, including six months in Russia at Dubna. Then I joined the US General Electric, working in Zurich for four years. I went back to Britain in 1967 to the University Of London Institute Of Computer Science, transferring to University College London six years later. I have been a Professor there ever since.

Throughout my life I have had a lot of transatlantic experience. When I left General Electric, I wasn't actually replaced for the next 25 years, so I stayed as an external consultant for GE. All this protracted European-US background is very relevant to my internet activities.

He is a Fellow of the Royal Academy of Engineering, and a Foreign Associate both of the American Academy of Arts and Science and of the US National Academy of Engineering. He was awarded the ACM SIGCOMM Award and the IEEE Senior Award in 1999. He became a Commander of the British Empire (CBE), and received the Internet Society's Postel Award in 2003.



P.Kirstein@cs.ucl.ac.uk
www.ucl.ac.uk

Do you remember when you had your first contact with a computer?

No, I don't quite know exactly when, but it was in 1951 when I first went to UCLA. There I saw a one hundred meter long mechanical differential analyzer and also **SWAC** (the South West Automatic Computer) I only saw that one at a distance. There were two computers built at roughly the same time, SWAC and the **SEAC** the South Eastern Automatic Computer.

So that's what I saw as my first one. Later, after two years of mathematics study at Cambridge University, I considered working with **EDSAC** at their Mathematics Laboratory. That was one of the most powerful, real computers at that time. Then I went to Stanford University. That was the first computer I used, which had 19 words of storage, was the IBM 605; that was the most powerful computer at Stanford in 1954, and was the first one I used in my microwave research.

What was your first contact/experience with the ARPANET?

Sorry to be long in answering these things but I don't quite know how to describe my first contact. In 1965 or 66, I was visiting UCLA and met a graduate student sitting up on the roof there - somebody called **Vint Cerf**. There Professor **Jerry Estrin** described to me the network they were building. At that stage, UCLA had three IBM 360/91s; one was at the Electrical Engineering Department, another at the Western Data Processing Center and the last one was at the medical school. Those three were going to be connected together with three IBM 360/40s as front-ends, and that was going to be a network experiment. This was actually the first network I had seen and it sparked off the idea of the ARPANET a few years later, because it was the first time someone had put a front-end machine behind a host.

Around this time I also saw, and discussed with **Donald Davies**, the first packet-switched network he was building at the National Physical Laboratory (NPL) in London. I chaired a session on the NPL network at IFIP in early 1968 - before the ARPANET was operational. (NPL discussed later on in this interview)



Already, in October 1972, when there was that famous ARPANET demonstration/conference in Washington DC, I was giving talks about the European Network situation. The European activity was deliberately complementary to what was going on in the US. Hence I suggested to **Larry Roberts** (the ARPANET Project Officer) that we in London would do something different from anybody else in the world; we would connect computers remotely to the ARPA TIP, which wasn't happening in the ARPANET community. Because all I had was a small computer (Digital PDP-9), I was going to connect to the CDC 7600 computer in the University of London Computing Center (ULCC) and the IBM 360/195 at the Rutherford and Appleton Laboratory (RAL).



which was some 70 miles away. I was going to connect them: looking one way exactly like an ARPANET computers, with all the right protocols, and the other way exactly like an IBM or CDC terminal. This was a new concept at the time. If you look at the early maps somewhere around October or November 1973, you will see the ARPANET terminates at UCL on my PDP-9 but the hosts are called the RAL IBM 360/195 and ULCC 7600. Later we added also the Computer Aided Design Center – this was a Depart of Trade and Industry Centre in Cambridge. Thus all those three were remote from me, but from the US side, they looked as if they were ordinary ARPANET hosts.

For the early RAL linkage we used the IBM HASP terminal protocols. In early October 1973 this link was already operational, and I gave a talk stating that this machine was on the ARPANET. After the talk, one of the RAL systems staff came up to me and said “that was a very good talk you gave, however of course, it wasn't true. We can tell because we have never seen any sign of being on the ARPANET”. I responded “That's exactly right, all you see is something that looks like an IBM HASP terminal, which is attached to you, but on the other side, it has got the whole ARPANET around it”. They were rather worried about that – but that had been part of my original proposal in 1971.

I had early financial and political problems getting the project started. While I was trying to get some funding from our Research Council, which I never really got, the whole activity was nearly ruined. **Larry Roberts**, then the DARPA Office Director, offered me an ARPANET Terminal IMP (TIP¹) and I put that into a proposal to the British Science Research Council (SRC). They didn't believe the offer, and the Chairman of the SRC wrote to the Director of DARPA (**Steve Lukasik**), requesting confirmation; Steve had heard nothing about this at all and so he asked Larry Roberts what was all this about, Larry was very upset that Steve had heard from the UK before he had been briefed locally on something as unorthodox as “exporting the ARPA network to Europe”...

Later I got to know **Steve Lukasik** quite well, and he approved of the idea. Since I was writing the proposal to a small department, pretty far down the hierarchy, it was surprisingly that it was considered important enough to go all the way up to the Chairman of the SRC and the Director of DARPA. I was also trying to get 20 or 30 thousand pounds funding from the Department of Trade and Industry, so I wrote to a colleague at the largest British computer company (ICL) for political support – not financial backing. After waiting for eight months, ICL finally replied that they had looked at the proposal very carefully, and concluded that it was much worthwhile to spend two weeks on a visit to the ARPANET in the US than to do it ourselves!

¹ TIP: *Terminal Interface Processor*. The first one was deployed in Sept. 1971, enabling individual computer terminals to dial directly into the ARPANET thereby greatly increasing the ease of network connections (compared to their bigger brothers the IMPs) and leading to significant growth. Later they were called *gateways* and nowadays we call them *routers*.



I am not sure if this is answering your *first contact* with the ARPANET question.

While I didn't get funding from either ministry, there were no objections from **Steve Lukasik**. Therefore I got 5.000 UK pounds from **Donald Davies** (from the British National Physics Laboratory) and the offer of a 9.6Kbps link to NORSAR near Oslo, where the transatlantic link to DARPA in Washington ended. The funding from Donald was the most that he was allowed to authorize from his own funds. Between 1971 (when the whole thing had started to be negotiated) and 1973 when the computer arrived, the British had introduced a Value Added Tax (VAT) that was 10 percent of the value of any goods. So, when this TIP arrived, I received a bill at the same time for 5.000 UK pounds in order to import the TIP - which was my total funding! So I stated that I would pay under protest, but would appeal the ruling. In the meantime the equipment should be released. After about a year and half, my appeal was turned down by the Treasury, who stated that it was a political issue, and I couldn't do anything about it. So I then wrote to the Treasury stating: "Alright, I will export this TIP, but since it belongs to the US Ministry of Defense, I will re-import it under the Exchange of Forces Agreement Act between the US and UK". They didn't like the sound of this. By this time (in 1975) I already had contracts from 6 ministries. I was then called in to a very high level officer of the Treasury who interrogated me saying: "What you're doing is of no interest to the Department of Health?" "No sir", I replied although I was running a link to the US National Library of Medicine. "It is of no interest to the British Library?" "No", I replied although I had a contract from them. "No interest to the Department of Education and Science?" "No", although I was running a service for all British universities accessing the ARPANET. They continued in the same vein with the Ministry of Defense, Trade and Industry and Atomic Energy Authority - with all of whom I had contracts to provide ARPANET services. Then the Treasury wrote me an official letter stating:

"Since your activity is of no interest to any British ministries and only to the United States Department of Defense, you have permission to import this and any subsequent equipment for this project free of tax and duties".

For the next 10 years, based on this letter, my small research group ran a complete international service. Whenever anyone questioned this, and wanted to run it themselves, I readily agreed - but pointed out that they would need to pay the taxes and duty on the computers which were, by that time, in different locations including the Ministry of Defense, British Post Office, and different university sites.

Shortly after my ARPANET link became operational, **Bob Kahn** at DARPA started a new satellite project called SATNET. The project



could not go live until arrangements had been agreed with COMSAT, INTELSAT, the British Post Office station at Goonhilly Downs² and the Tanum earth station in Sweden, which ran the transatlantic link to Norway. To extend the project, he was discussing also with three other countries³, Germany, Italy and Canada.

By 1973, the British had already nation-wide access to its large RAL IBM-360/195 via a centralized IBM network. At the same time there were two other centralized networks: one was based on a ULCC CDC 7600 in London and the other on the ATLAS at the Computer Design Center in Cambridge. Because they all already connected in remote computers, albeit with proprietary protocols, they were suitable for connecting to ARPANET. In practice, the CDC one didn't work very well because they had the wrong sort of protocols, we couldn't do anything very interactive. The others were all on for quite a while and in the meantime the networks around them grew and I had to change and convert what we were doing to make it still stay transparent to the US.

On **July 25th, 1973**, the University College London node of the ARPANET passed its first data packets between London and the Information Sciences Institute in California, USA. This is believed to be the first instance of an international heterogeneous computer network;

Of course, we had many other problems, for example that involving our Domain Name. The **.UK**, via UCL, was the third domain name to be adopted (after **.EDU** and **.US**). In 1983 I chose **.UK** because that covered Great Britain and Northern Ireland. Around 1986 **Jon Postel** was trying to put some order into domains and wanted to have the top-level country names aligned with the list published by the International Standards Organization. Unfortunately the British Department of Trade in the late 1920s started talking about car registration and they decided (incorrectly!) that the British country code should be **.GB**. Thus Jon said to me: "*Peter, you've got to*

² Vint Cerf wrote when asked on this topic: Before UCL was put up on the ARPANET, only the NORSAR (Norway) facility was connected by satellite. Bob Kahn worked out an arrangement to increase the total capacity of the system and also arranged for UCL to be connected to the ARPANET. Initially NORSAR was connected to the ARPANET by a dedicated satellite connection. The capacity was increased and UCL was connected to NORSAR by land line, thanks to the generous offer of the British Post Office. The satellite ground station was at Tanum, Sweden. Later, the Packet Satellite system was fielded via INTELSAT IVA and UCL was connected to the SATNET and the land line to NORSAR was removed. UCL was connected to the SATNET through a ground station at Goonhilly Downs, (UK). NORSAR/NDRE was re-connected to the ARPANET by way of SATNET which also used a ground station at TANUM (SE).

³ Germany and Italy were no particular problem; they happened but they never did anything because they never had the infrastructure and there were too many problems with what they were allowed to do. Norway never went very far for the same sort of reasons and Canada never got started for a very interesting different reason. In Canada, it was Bell Northern who was interested; it was responsible for all communications with the USA. All Canadian satellite communication was the province of OTC. OTC was unwilling to give up their exclusive rights to international satellite communication, but Northern Telecom was unwilling to compromise their exclusive rights to connect to USA. Since those two couldn't agree, Canada could never join. Comsat was a partner; through them we had also some smaller stations connected in.



choose, you can't have two and .GB is the proper⁴ one, so you've got to choose whether you would use .GB or .UK". There was a 4 or 5 years period in which we were discussing this backwards and forwards. The British authorities rejected on principle being dictated to by the Americans on this; you can imagine all the rest. Even in 1988, it was estimated that it would cost 25 million pounds to change to **.GB**, and nobody was prepared to foot the bill. At one stage I guaranteed to Jon Postel that within one week of his moving all of the United States onto the **.US** top-level domain, I would move all of Britain onto **.UK**, but he didn't think this was very funny. There was an even worse suggestion; one Briton wanted to have **.UK** whenever one was using the ARPA/internet protocols and then **.GB** when using the OSI protocols. I refused that proposal, saying that was just not the way things are supposed to be done. In fact **.GB** still exists, but I do not think it is used. I am not sure if the MoD⁵ has stopped using it.

The ARPANET grew steadily in the early 70s, and Cerf and Kahn proposed their revolutionary Internet Protocol in 1974. By the time that daily traffic on the ARPANET exceeded 3 million packets, in 1975, Bob Kahn from DARPA decided to fund three contracts: one at Stanford, California (with **Vint Cerf** and his students), another at BBN, Cambridge (with **Ray Tomlinson** and **Bob Thomas**) and the third to us at UCL to develop and implement what at the time was called the Kahn-Cerf TCP protocol. The Stanford team produced the detailed specification and within about a year we had three independent implementations of TCP that could interoperate.

Because of our early experience with TCP/IP – and with the corresponding OSI protocols adopted by the British networks, the UCL gateway was the first to use the internet Protocols exclusively for service⁶.

One of the principal mechanisms to keep the whole project working was that I set up a Political Governing Committee (GC) with representation from all organizations providing budget. Originally this included someone from the British Post Office (part of which later became British Telecom), somebody from the academic side, and originally NPL representing the Department of Industry (DoI). In 1974 I wrote to the Ministry of Defense (MoD) because the whole project was in danger of collapse. They sent the chief of guided missile to talk to

⁴ As for 2010 only one sub-domain is still registered in **.GB** (ISO 3166-1 official code for the United Kingdom) and no new registrations are being accepted for it. Sites in the UK use **.UK** as their country code Top Level Domain.

⁵ MoD: stands for the Ministry of Defense.

⁶ As my PDP-9s (which I bought in 1968) was getting rather long in the tooth by, in 1979 I had to get rid of them; there was no point in putting in the ARPANET NCP again so I started putting in the internet protocols (TCP/IP) and started running services with them. After all, 12 years was a long time for a communication computer with at most 32K words which had to do all the work of translating protocols, changing domains etc. Anyway, we went into service somewhere around 1981, well before the main switchover. We complained because it was just not ready even though we had to run an international service on it. It was only when our US colleagues started running their services after the switchover day in January 1983, that our US colleagues started to understand why we had been complaining.



me and they decided to give me a contract also. Various people for instance **John Taylor** was the first person on my GC from MoD; he later became the Director of the Research Councils. There was always somebody from MoD on the CC; **John Laws**, the MoD GC member took a guess around about 1985/6 when the first question of .GB came up, that it would be the one that would win the battle, not UK. Hence he moved some of the MOD people onto GB but he couldn't move them back.

Making things compatible on both sides:

The whole principle of my service hinged on whether one could or couldn't manage these major differences between the two sides. For instance, file transfer in the ARPANET was interactive; in the British system, (so called colored books), it was a batch link; how do you give reasonable responses when you are trying to go between such things? We were very deeply involved in all the British systems, which all were based on what the telecom companies were doing at the time.

The standards were described as the so called *Colored Books*; we obviously participated in the formulation of those, particularly in the Grey book (about email). It was a European project, yes, and a British one. The British really pushed the *Colored Books* themselves. To keep our connection and system working we had to be completely *Colored Book* compliant in one direction and then completely ARPANET-compliant the other way. So what one could and couldn't do on that was already important.

We were heavily involved in SATNET and some of the packet voice activities at the time. I believe we were the first to send facsimile over the ARPANET/ We also we did some measurement because around about 1977 the British started putting in their own packet-switched service⁷.

We were part of the SATNET experiments, but then somewhere around 1979, SATNET stopped being an experiment and the Germans, Norwegians and Italians, stopped participating. However; we ran SATNET as a service for the next six years. Actually some of our traffic ran over SATNET and some over the International Packet Switch Service (IPSS). IPSS was based on X.25 protocols. We did some measurements on that, for British Telecom.

In your opinion, what are the key characteristics of the Internet?

⁷ First of all in 1977 it was called **EPSS**: Experimental Packet Switch Service then called **PSS** Packet Switch Service and later on changed to **IPSS** International Packet Switch Service.



Well, I think one of the most important one is that you have a particular level at which interconnections are possible and that you can isolate things both above and below that particular level. That means you can have different network technologies below that level and different application technologies above that level. The fact that it is a universal level with a well-known interface, gives one a lot of freedom in what applications one connects with and how one connects with different network topologies.

The problem is the protocol isn't completely optimal, so as long as I remember, there have been attempts to break through the rigid levels and optimize things below or above. Of course if one does, one is going to break this universality, but it will become more efficient. We have had this dichotomy for as long as I remember; it is still there.

People are putting QoS (Quality of Service), signaling what you need for security, etc. That's always been the key problem is that you had the capability of having the isolation and then you fiddle either above or below with various mechanism for guaranteeing quality of service or security or anything else. This is not a show-stopper, it works fairly well, it works better now than it used to because we can now over-engineer on bandwidth. It is interesting actually; one of my main projects now is concerned in introducing the internet satellite based in new developing countries. We have limited bandwidth; 30 Mbps for the whole two regions of the Caucasus and Central Asia. Nevertheless, we want Voice over IP and videoconference; one can do that by putting in the right Quality of Service (QoS) in the routers. We define terminals, which should get priority and then those go faster. We are technically able to do that. But on the other hand, that's very heavy work on the routers; so what I have ended up doing is over-provisioning the bandwidth, to increase the quality, lowering the routers' work.

I am a great believer in IPv6, which I think will certainly happen – even though current acceptance is very slow. The main reason that it will make it happen is because so many of the newer protocols are being



aligned for the IP_{v6}, so sooner or later it will have to happen.

The other characteristic is the big scalability of IPv4; the fact it survived at all from the original experiments in 1975 to what happened to it in 2006, is really incredible. We always thought about doing a few conversations over this



thing but to actually have the level of real-time traffic we now have, was never imagined at all.

Then of course the next is the various application-specific protocols, in particular of course, the web. One thing which still needs working through is the fact that there are a number of different ways of doing security and that causes real problems – which I don't see any sign of that being resolved. There are too many vested interests. VPNs mean that you have one form of control by one set of organizations. You can try to mandate IPSEC but you're not going to have that done on the mobile side because the mobile operators want to have security based on the SIM cards that they control. The fact that you have so many different types is very unfortunate and yet inevitable.

What do you consider the most important milestones in the development of the network?

- 1974 I think the first really important milestone was the concept by Bob Kahn, of having completely different networks, at some level in protocol, to work together. Analyzing gateways that could work and we finally realized that in 1978.

Vint and I wrote (the only joint paper we have ever written together) specifically analyzing gateways and different types of issues which could exist. He was my project officer⁸ in DARPA at that time. We had contracts for some 30 years, and gave reasonable value for the small contracts we had with them. Clearly, the concept of connecting networks was the first really important one.

- 1983 The next really important one was actually putting network connection into large-scale practice. That came in several ways; on the one side, the introduction of TCP/IP altogether and second of all, the growth in access networks, separate from the backbone networks, but still using similar protocol structures, very easily connected.
- 1984 Clearly the DNS, which was not part of the original TCP/IP concept was a huge advance.
- 1991 And then of course, the next biggest milestone was the winning of the protocol wars (TCP vs. the “official” OSI from ISO), which was an absolute and complete victory.

⁸ You see I have always had on the one side these people I mentioned in UK, then a distinguished set of project officers from DARPA because I had DARPA contracts from 1973 to 2003. The list of people who were my project officers is a very distinguished list; It was originally **Larry Roberts**, later it was **Bob Kahn**, then **Vint Cerf**, **Steve Crocker**, **Paul Mockapetris**, **Mike St. Johns**, **Hillary Orman**, **Doug Maughan** - all the people you know of one way or the other; they all have been my project officers and we were always putting a slightly different flavor on things.



- 1992 The fact that the simple World Wide Web concept met so many of our needs, and could use a single underlying network ensured the phenomenal growth and universal take-up of the Internet that we have now seen.
- The milestone that I am still waiting for is when there's a real acceptance in the US that IPv6 is a good idea. So far, all of the manufacturers are providing it but there is a very big sign of data. The real people pushing for it are the Chinese and the Japanese. In fact the main reason for Cisco went into it was because of a NTT request for tender, which requested that IPv6 be available and Cisco couldn't respond; Cisco doesn't like not being able to respond to a large tender request!. So immediately they put in an IPv6 program and coordinated a large European project (6NET). Now, all the American companies have implemented IPv6 on their products. By that I mean it's completely standard on Microsoft products, it's completely standard on stack on Cisco and Juniper routers. It's a chicken and egg situation; there's no immediate shortage of address space in the United States. When the US runs short of addresses this will be a major boost to deployment. As soon as the US crosses over to deploy IPv6, other countries will cross over too. It is because there's much greater address shortage in Japan and China that they have embraced it first.

Why were we connected through Norway to the US-ARPANET?

The reason for this is that there was in 1971 a Nuclear Monitoring Research Office (NMRO) in DARPA. That was doing seismic monitoring and operated three large seismic arrays in Alaska, Montana and Kjeller (Norway). The data went via 2.4 Kbps data links to the Seismic Data Analysis Centre (SDAC) in Washington. For this reason there was a 2.4 Kbps satellite link from Washington to the British ground station at Goonhilly, and thence by landline to Kjeller.

Larry Roberts' initial idea was first to put the NORSAR array onto the ARPANET to ease the data transmission, and then to increase the line speed to 9.6 Kbps, interrupt the link in London, and put us onto the ARPANET. He thought that this process would be straightforward, and would not need much funding. For the first stage, It was fairly easy just to put in an extra IMP; he was already deploying 40 or 50, so putting one more in Norway would not be very difficult. They could see already then, that they are going to need to expand their monitoring network.

For the second stage, Larry did not understand the problem! He thought he could just interrupt the line in London, re-terminating at UCL; add an IMP, and then go on to NORSAR at nominal extra charge. He did not then realize the international tariff problems. In fact the expenditure would have been very significant for the extra link. He



was not prepared to pay this extra international communications cost, but I persuaded the British Post Office to donate it to me for a year.

In fact the Nordic Satellite Earth Station came on stream in 1972, and there were various other changes in the following years. Thus the timeline is given below.

1970: US started receiving seismic data from the NORSAR array at 2.4 Kbps via satellite link to Goonhilly and then land-line to Kjeller.

1972: NORSAR Seismic data goes to US directly through Tanum (Sweden) by Satellite and thence land-line to Kjeller.

1973: NORSAR link upgraded to 9.6Kbps. ARPANET connected to Kjeller Computer Centre. UCL connected by 9.6 Kbps terrestrial link to Kjeller. Link established UCL to RAL.

1974 Links established to Computer Aided Design Centre (Cambridge), Fusion Research Centre (Culham) and Blacknest Research Centre (AWRE, Aldermaston, seismic monitoring)

1975: SATNET starts, direct US-UK link (Post Office & UCL) using Intelisat IV

1976: Terrestrial link UCL - Royal Radar and Signal Establishment (RSRE) opened by Queen. SATNET extended to Norway, Germany and Italy.

1977 EPSS link giving national access through packet-switched service

1979: Major demo using TCP/IP from RSRE via ARPANET (UCL) then SATNET (to Washington) then ARPANET (to SRI in Menlo Park) to Car on Bay Bridge (using Packet Radio). Alternate link to ARPANET established via IPSS international packet-switched service.

How did you contribute to the development of the Internet?

- First of all, not only having ARPANET become international, which was just a question of **Larry Roberts** giving me the TIP and link, but developing this into a real user community, first of all in Britain. We must compare what happened in the UK with what happened in Norway, Italy and Germany, which all had satellite IMPs from ARPANET as well. The services didn't develop in any of them, because in none of those three other countries there was the effort devoted to bringing in a user population and to coordinate whatever was happening nationally with what was happening in the US. It was being much too optimistic to think you



could bring it in such a radical different concept, and import it straight into the European countries. It was necessary to follow what was happening in Europe, track it and to adapt things to your country – which required political and technical effort and prolonged dedication (on both sides of the Atlantic). What I did technically to connect the heterogeneous networks was novel and it worked. However, it was not efficient, it was never going to scale to where we wanted the Internet to scale, but at least it made it possible to get a lot of experience of it. From the beginning when, they moved ARPANET over from NCP to TCP/IP (in January 1st 1983), we were able to move over to the proper internet as it is today.

- The time line above showed that the UCL activity was much broader than just academic. The links to RSRE, Culham, Blacknest and CADC all went well beyond academic links, and brought in the support to maintain the service.
- Our contribution also kept the US side much more internationally minded. I don't know if you are aware, that in 1981 Vint Cerf started two different activities; the international collaboration board (ICB) for the defense and the international activity board (IAB). I ran the ICB from 1983 to about 2003. It was small, it only had some 6 or 8 defense departments (from Canada, the UK, US, Germany, the Netherlands, sometimes Norway, NATO and Denmark); that was small but at least it kept the international presence going on for these things. I killed it when DARPA said the thing could no longer attend if it was outside North America. I felt that it was no longer International enough, so there was no point in continuing it. It was not so much for cutting expenses; it was much more that part of the US became more introverted.
- Another important point was that it broadened the US international interest. It was the success of our activity that had the US National Science Foundation approach us in 1983 to forge other international links. These I arranged first bilaterally and then with other countries around one of my ICB meeting (see above). Incidentally this also led to discussions amongst the US agencies (NSF, DARPA, Energy and NASA) on joint funding of links.
- There are other contributions. We were very heavily involved in multimedia for a long time; these things were originally just UK-US but later became very much European-US as well. So, for instance, I ran a whole series of multimedia European projects which had me collaborate with the US for quite a while.



During the personal interview at the Kelvedon Hatch secret nuclear bunker (UK). October 30th 2006.

I would say bringing the ARPANET to the UK was comparatively easy but to develop a user population was much more difficult.

Who are some key people in the development of Internet, leaders or trendsetters?

First of all, quite clearly **Larry Roberts** for starting things off and then **Bob Kahn** made the key decisions over the next twelve year, **Vint Cerf**, **Jon Postel**, **Steve Crocker** and **Paul Mockapetris** played vital roles – probably reflected I other contributions in this book. I think one of those who are clearly under-credited and under-rated is **Dave Mills**; he was the first person who broke the monopoly of the gateways; he put together his own gateway called the *fuzzball*. The big impact it had was clear since at one stage there were 50 fuzzball nodes (at the NSFnet) all doing different things.

Technically the most important contributors in the UK to the UCL activities were **Peter Higginson**, **Jon Crowcroft** and **Steve Kille**. Peter was responsible for all our early software until he left our group in 1976. Jon has played a vital part since 1979. He was a key player in our relations with DARPA, and been very influential in Internet developments. Steve played a vital role in maintaining the integrity of our gateways throughout the 1980s, and ensuring that the UK mail and directory standards were as compatible with the Internet as possible.



Donald Davies, of course, has been key. His contribution has been more from a theoretical point of view, than the internet point of view. Davies created the NPL-network but the problem with it was that it was an *in house* network only; they were never able to get any funding at all for going outside NPL. Davies was in particular concerned with the **EIN** (the European Informatics Network). He started up that network putting things in from NPL and getting others (particularly France with **Louis Pouzin's** *Cyclades-network*) and ISPRA (in Italy) among others.



We also used International packet-switched services (from ARPANET), but Donald Davies was never able to do that; he was never able to get out and that was very sad.

Paul V. Mockapetris for creating in 1984 the Domain Name System (or DNS)

Another one extremely important but you don't hear much in these days, on the radio side is **Jim Matthiis**. Also on the routing side, **Dave Walden** was always very important. **Frank Heart** (BBN group leader) did a very good job on the switch (the IMP⁹) part but it was not in very strategic portion of the Internet, He was not involved in the internet side of the thing at all, as far as I know. The IMP was a packet switch. **Ginny Strazisar** was fundamental creating the first gateway ever. Somebody else (who again is forgotten about, but probably did more to revolutionize things than anybody else) is **Leonard Bosack** (Cisco co-founder). And by the way, we had the first Cisco router in Europe here at the UCL - and still have it! Len was showing it in Paris and later dropped it off in UCL. Len, made a successful product of this, when nobody else was really competing with PROTEON (then the router leader). We all know PROTEON died whereas Cisco flourished. Of course it did require **John Morgridge** to make Cisco what it is today.

And of course, **Bob Metcalfe**, because again, the Ethernet was absolutely vital and is now everywhere. One who could have had a strong impact but in the end didn't was **Maurice Wilkes**, (Cambridge UK). He didn't because even though he invented what could have been a good access technology, (the token ring) he didn't like to bother with standardization - so that it never really took off. One of the really far thinkers is clearly **J.C.R. Licklider**; while he had little to do with the internet itself, he was thinking broadly around this.

⁹ IMP: Stands for Interface Message Processor. Created at Bolt Beranek and Newmann in 1969.



You can't omit, of course, **Tim Berners-Lee**, but that's obvious. I think the first person who probably put more order onto the security side than anybody is **Steve Kent**. Steve is really a very intelligent person and he has followed this security issues from the beginning.

Len Kleinrock started a lot on making measurements respectable, but actually the person who has really done most on the measurement side is **Kimberly C. Claffy**, she is the one who has done more than anybody else in measurements lately and she ran a part measurement center at UCSD - even though she is not an old timer.

A couple of anecdotal situations

- So just to give you a simple example, the DNS came in around 1984. At the same time the British were developing the *Network Resource System* of UK hosts. The Americans (Paul Mockapetris et al.) decided the way how to do was to express my address as `kirstein.cs.ucl.ac.uk`. The British always know better, so they decided to do it as `kirstein@uk.ac.ucl.cs` (just the opposite way). I tried to persuade the British to change, they said "what right has a small research group to change what we do nationally?" so I tried to get ARPA to change "what right have you a small foreign research group to change what we do in the United States?" So I had to update both sets of tables every night to keep them compatible. I then had to look at every message that came through our gateways, and work out which way around the domain name should be - since often people send their address to each other in messages the other way around! Our algorithms worked very well until 1986 or 1987 and then there was a disaster. Czechoslovakia joined the internet! Czechoslovakia has the country code of **.cs** and when we got a **.cs** (short of Computer Science), I couldn't do it anymore; there was no way anymore to guess which way round it should be. Finally even the British changed it, in the early 1990s.
- I had told you that I had my Governing Committee and they insisted that I put access control and accounting in our network because they were worried that one part of the Research Council would pay too little compared to another part. I had to do very careful accounting. and because I had been given a 48 Kbps free line by British Telecom to do some measurements for them (a 48 Kbps transatlantic link was a lot for 1979/80; it was the analog version of a 64 Kbits digital line). I also had another 9.6Kbps one with X.25 and then SATNET, which was 64Kbps. I had to have access control and accounting available, but I didn't particularly bother to turn it in the direction from the US to the UK. I put all the traffic one way so I paid the minimum and I didn't look at the



accounts since I did not have to pay. Then the Governing Committee, instructed me to put on access control both ways. Therefore I sent out a message to everybody who had passed through my system in the previous 3 or 6 months, using the e-mail addresses from my accounting system, saying that we had automatic logs already and that in 2 or 3 months' time we would apply access control. We would block all traffic from those who had not registered and had not been approved to use the link. At this, if I may use an expression, *the shit hit fan*; I suddenly got a storm of hate email the like I have never had before or since, from about 5.000 people; Many were from third countries - even though I was strictly forbidden to do international communications at that the time. Nobody had realized that the Internet had actually happened, that people were going one way through UNIX email, through BITNET, through any number of different ways and then automatically, because that's the way the DNS works, were coming back through the cheapest, the quickest, or the best route; through my link. The e-mails berated me stating "what right do you have to block my email?" They had no idea they were using my system, it was completely automatic that direction. One suddenly realized that nobody had the slightest idea what routing topology was in place. We had no idea - but nor did anybody else; we knew who were going through only because we had many weeks of automated logs; we just had not had any reason to consult them. We thought that we were running a complete national service; in fact it was even more than a national service because by that time there were also European direct connections and nobody had any idea anymore who was going through what. Everyone thought they were living in a closed world, but they weren't.

- And by the way, Andreu, here I must take exception with one thing you said in your public speech today at the *secret bunker*. You talked about "switches" and then said, "Which we now call routers". But of course, they are very different. We now have proper gateways; there can be a completely different communication system on two sides of a gateway. This was what had happened and made a big difference even though not all used the Internet Protocols.

The Gateway genesis:

- DARPA was developing three different networks: packet radio, packet satellite and ARPANET. Whenever one wanted to make any change in any type, this was in 1973/1974; the only people that could do it were BBN - because they were developing all the



switches' code. With every change we were told that there would be a delay and significant costs. **Bob Kahn** was very unhappy about that and the original reason that gateway development was put in place was in order to have key separation between the network-dependent part and their interconnection. Thus he hoped to end his complete dependence on **Frank Heart's** group at BBN. In practice, another division of BBN won the contract to do gateways, so the monopoly stayed with BBN. However, since it was a different group (with **Ginny Strazisar**) doing the gateways it made a huge difference and allowed others to work in parallel, **Dave Mills** was developing a gateway too (the *foozball*), and this proved one of the most important developments that led to the Internet as we know it.

- In the early days international switched communications was completely the monopoly of carriers. You weren't allowed to have switched telephones attached to two portions of a leased network, or multi-country communications. I remember early on, in 1975, the British RAL Network that I've talked about already included leased lines to my complex and CERN in Geneva. I got a request from CERN, could they link to the ARPANET from CERN through us? So I had to pass the request to my Governing Committee. Of course what we were doing to prevent this. My problem was that I was allowing anybody on that centralized research network to use ARPANET, but had to prevent anyone in CERN going through? So I wrote back: "The following five methods they can get through, I can prevent. The sixth method that I can't prevent is the following; XYZ. Shall I put up a notice at CERN, saying you mustn't do XYZ, ABC because otherwise it would illegally go through to the US"? They decided I shouldn't put up that notice.
- All of these activities took a lot of work, it's not for nothing because we started thinking very early on about access control and security and that was important. We got to be very heavily involved on that later of course.
- "Incidentally, the German, Italian and Norwegians did not pursue a similar route. In the late 1970s, their growth of National Research networks was much slower, and quite divorced from any strong Internet links. Moreover, they had no equivalent of the UK Governing Committee, and never persuaded their Carriers to agree to the liberal interconnection policies adopted by the British Post Office and later British Telecom. For this reason it was not possible for a significant academic involvement from those countries with their US colleagues, until USENET, EARN and other similar Internet developments took off in the middle 1980s". [Excerpt from Ref #2]



What do you think about the future of Internet?

The first think, I am very interested on watching Internet's impact on areas it hasn't gone to before, where the impact is huge. I get amused to some sense that history is repeating itself. The problems we had in the 1970's and early 1980's in getting the need to support for research communities accepted in the UK, the rest of Europe and Japan in the late 1980s and 1990s are surfacing again in many other countries I deal with. We have just done a short report on the status of funding and services in the newly independent states in Central Asia and the Caucasus and virtually none of them have state funding for their research networks. We are putting in money from NATO and UNDP and a few other people but there is no national funding yet. They still don't realize its importance; the same happens of course in Africa.

When IPv6 does come in properly it will have an immense impact; sooner or later it will do something even about the address shortage going on in several places; that will have a major impact on services you have to use.

It is obvious that the need for speed is always going up. I see very clearly that the battle to have all real-time services going over IP has been pretty well won. What impact it is going to have on the whole communication perspective of companies, is not clear yet. This will be particularly relevant to energy provision – where the disadvantages of IPv4 and NAT provision are not yet realized by either the suppliers or their regulators.

The battle of circuit switch telephone exchanges is over too; circuit switching will disappear in the short – medium term. The impact that this will have on the finances of the whole communication industry is not yet evident. It is went very well for *Skype*¹⁰ to say that this thing is free but that implies that there's new infrastructure and how that infrastructure is going to be maintained under this, is not clear. The whole question of convergence and how much the mobile and entertainments industry will change is still not clear.

There' is a lot of re-arrangement and many things happening in the telecom industry but it is already all related to the internet.

Do you see any technological trends?

¹⁰ skype: is a software application that allows users to make voice calls over the Internet. Calls to other users of the service and, in some countries, to free-of-charge numbers, are free, while calls to other landlines and mobile phones can be made for a fee. Skype was written by Estonia-based developers Ahti Heinla, Priit Kasesalu and Jaan Tallinn, who had also developed the file sharing P2P software called Kazaa.



Well, obviously fiber yes, fast switches yes, I think satellite will continue in the parts of the world I deal with; it's quite clear that fiber will take over in principal places and cities but if you look at geography or topography of central Asia, there's no chance that fiber would go through all the places.

October 30th 2006. Peter Kirstein during the interview at the Kelvedon Hatch secret nuclear bunker with the author.

So the strategy we have is we are putting in satellite now, we expect to be able to put in fiber to the main cities within the next 5 or 6 years, and then we'll move the earth stations more to the remote regions of the countries; I think that's what is going to happen. It's a NATO effort, it's my job to do a little bit of deal making so NATO is paying for the main part of communications, and I have persuaded the European Commission to pay for the management of a NATO project, which I think it's the first time it ever happened. I persuaded *Cisco* to donate a local area network in every country, nine countries to go between the earth station and the national research network and then we got a little bit of money from ISOC and a little bit of money from various others. The World Bank is interested in doing video conferencing in some of the remote places, we have put VoIP terminals and a video conferencing system in each of the countries and we are now working the desktop conferencing. These are, of course, things that we used to do 20 years earlier in the West.



Lessons learnt

“A key factor in the early start of the project was that a small number of key people could make individual decisions and investments for a speculative project, in a way that was quite impractical for larger committees.

Second was the lucky chance that Government intervention, in the form of the Customs and Excise, forced the project to remain in private hands in the UK; if it had been under a Government Agency, it would surely have been killed at some vital juncture in its first decade.

As an example of the danger, I was requested by one Agency in the late 1970s to stop working on the Internet Protocols and work exclusively on International Standard ones; needless to say, I refused. In private hands, even when the going was rough from one source, another could be mobilized”. [\[Excerpt from Ref #2\]](#)

ADDITIONAL READING

PAPERS & BOOKS MENTIONED / RECOMMENDED

- [1] Vinton G.Cerf, Peter Kirstein, “*Issues in packet-network interconnection*” *Proceedings of the IEEE*, pp. 1386-1408, November 1978.
- [2] Peter T. Kirstein, “*Early Experiences with the ARPANET and INTERNET in the UK*”, Department of Computer Science, University College London, 1998.
- [3] Peter T. Kirstein, “*The early history of packet switching in the UK*”, *IEEE Communications Magazine*, Vol. 47, no. 2, February 2009 , pp. 18-26